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REF DATA DICTIONARY SPECIFICATION FOR COMPUTATIONAL ELECTROMAGNETICS

Decision-Science Applications, Inc.

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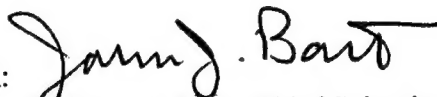
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13. ABSTRACT (Maximum 200 words) The Research and Engineering Framework (REF) manages data for a variety of design and analysis codes. Each of these different codes has its own data requirements (data model) for input and output. The method that the REF uses to handle these different data models is through the use of a data dictionary. By utilizing the data dictionary, REF users will have the ability to switch between data models thereby transforming the generic REF into a discipline specific design system. This report documents the effort to design and develop a computational electromagnetics (CEM) specific data dictionary for the REF. Types of data covered by this dictionary include: CEM analysis techniques, geometry elements, material properties, excitation information, and observables information. The CEM data dictionary has been developed as a baseline data dictionary for the wide variety of CEM codes available. A developer need only tie his/her application specific code into the REF directly or through a code interface wrapping to access this data dictionary.				
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1. INTRODUCTION

This report documents a 9 month effort undertaken to develop a data dictionary that will cover the broad spectrum of data types used in the computational electromagnetics (CEM) field. This effort is entitled "REF Data Dictionary Specification for Computational Electromagnetics", program contract F30602-95-C-0049 to Rome Laboratory (RL/ERST).

2. BACKGROUND

During the 1960's, frequency and power levels obtainable from solid state devices began to seriously compete with those of microwave power tube devices. In the 1970's, the lower labor costs of foreign manufacturers further reduced the domestic share of an already eroded commercial power tube market. These factors have resulted in a reduced and uncertain domestic supply of microwave power tubes. However, because solid state devices are not able to meet all power and frequency requirements, a number of commercial and military systems (notably radar and communication systems) still require vacuum devices.

In 1972, the Advisory Group on Electron Devices (AGED) issued warnings and published several reports highlighting this situation. The problem is further complicated by increasingly demanding system specifications and increased labor, material, and production costs. Since the military services are the largest customers for microwave and millimeter-wave tubes, the industry remains of great importance to national defense.

One critical government initiative to improve the power tube design process is the Microwave and Millimeter-Wave Advanced Computational Environment Project (MMACE). The MMACE Program will provide the microwave and millimeter-wave tube industry with an integrated design, simulation, prototype, and manufacturing software environment to facilitate the development of complex tube systems which, in turn, will reduce cost and time to market.

The Research and Engineering Framework (REF) is an outgrowth of the MMACE Phase II program where, over the next three years, the tools will be developed to simplify the development of a design framework for scientific design and analysis environments including Computational Electromagnetics (CEM). The REF manages data for a variety of design and analysis codes. Each of these different design and analysis codes has its own data requirements (data models) for input and output. The method that the REF uses to handle these different data models is through the use of a data dictionary. REF users will have the ability to switch between data models thereby transforming the generic REF into a discipline-specific design system.

The primary objective of the data dictionary is to act as the interface between the generic REF environment and discipline specific tools thereby making the framework usable by applications connected to it. Figure 1 shows how the data dictionary fits into the framework. Although the REF can manage a variety of different data entities and data types, it has no inherent knowledge of which data entities are needed to support the codes plugged into it. The Data Dictionary solves this problem by acting as an automated lookup table mapping code requests to the data storage.

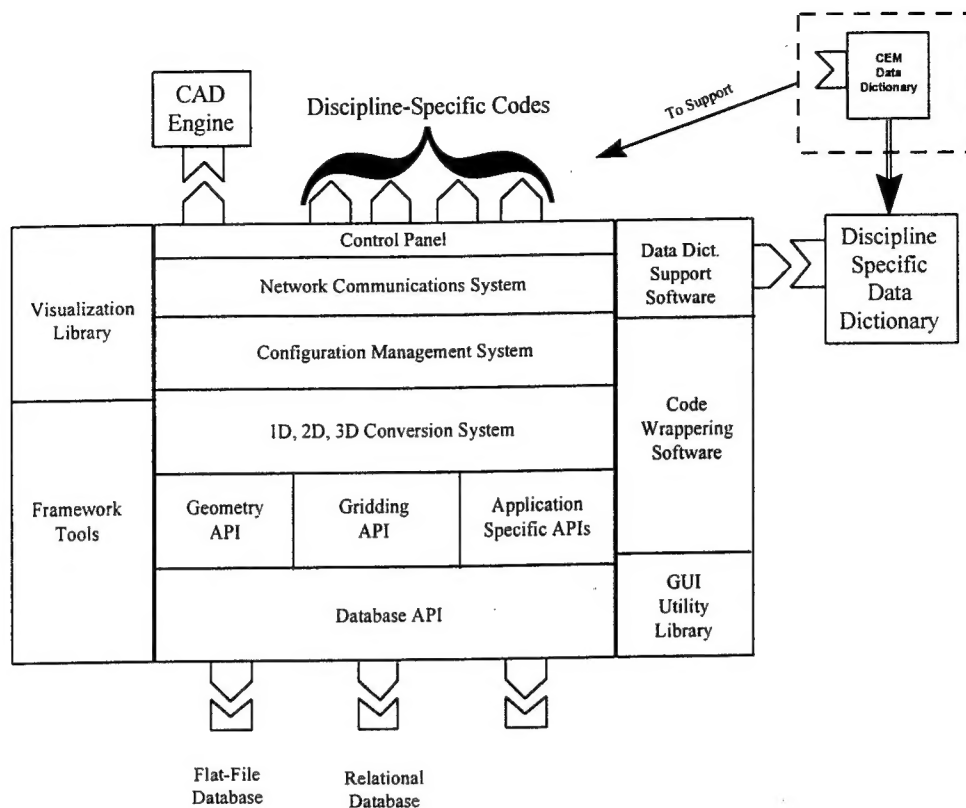


Figure 1. CEM Data Dictionary Placement in the REF

3. DATA DICTIONARY DEFINITION

A Data Dictionary is a database containing data about all the databases composing a database system. The content of the data dictionary may best be thought of as “data about the data”—that is, descriptions of all of the other objects (files, programs, and so on) in the system. In particular, a data dictionary stores all the various schemas and file specifications and their locations as well as information about the structure of the database. The data dictionary is consulted before actual data is read or modified in the database system. A complete data dictionary also includes information about which programs use which data and which users are interested in which reports. The data dictionary is frequently integrated into the system it describes.

A relational database system needs to maintain data about the relations among the data. Included in the types of information the data dictionary stores on the system are:

- Names of the relations
- Names of the attributes of each relation
- Domains of attributes
- Names of views defined on the database, and the definition of those views

- Integrity constraints for each relation (for example, allowable ranges for attributes in the relations)

This is a preliminary list of the data dictionary elements that would need to be addressed to incorporate a CEM capability into the REF. It may need to be refined once the implementation has begun.

The following figure shows a fundamental structure of the type of CEM database we are attempting to develop. This database layout has as its “leaves”, or lowest nodes, those defined for CEM specific applications. The CEM data dictionary is designed around the concept of an analysis of a system. The system can be any object that radiates or scatters EM energy. The formulation used in analyzing the system is based on the commands stored in the database for that analysis. The Data Dictionary design is being developed to be used as a data storage template for existing CEM tools and new CEM tools. This is possible because of the supporting set of development APIs (Application Programmer Interfaces) in the REF. These APIs allow existing codes to be incorporated into the REF and also provide the developer with a robust set of code that provides the connection to databases, graphics, gridding, etc. These APIs allow the developer to concentrate on the EM development rather than worrying how he/she is going to store the data.

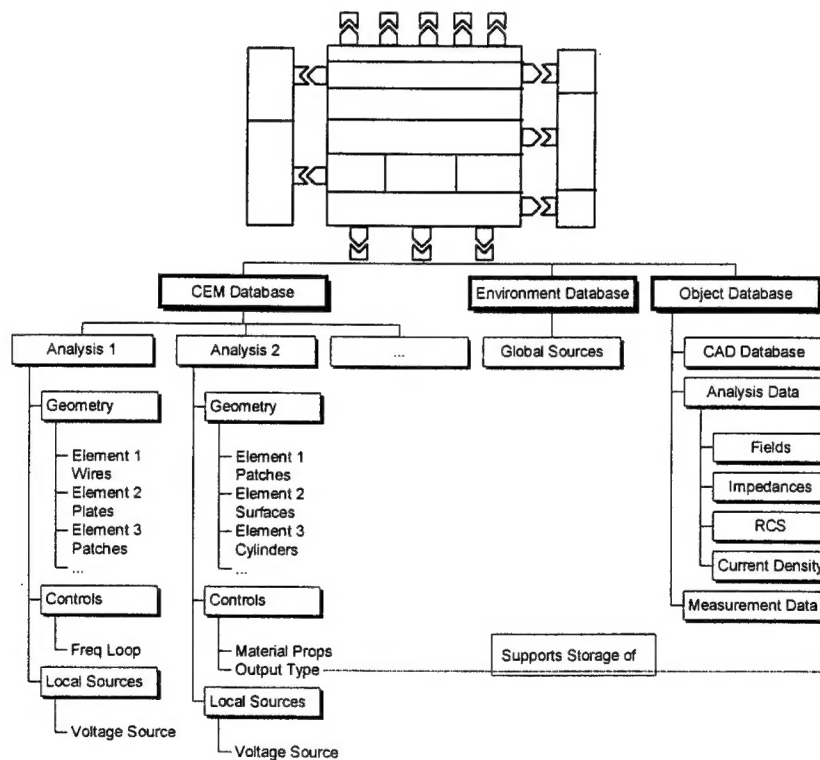


Figure 2. CEM Data Dictionary Concept

One method to incorporate an existing (legacy) application into the REF is shown in the following figure. This method of interfacing the legacy code into the REF allows the user to take advantage of the data handling, storage and display capabilities of the framework. A code interface wrapper is generated that will read data from the REF database and place it in data files to meet all

requirements of the legacy code. These inputs files, which are in the format of the legacy code's native format, can be used directly by the application without any modification to the application.

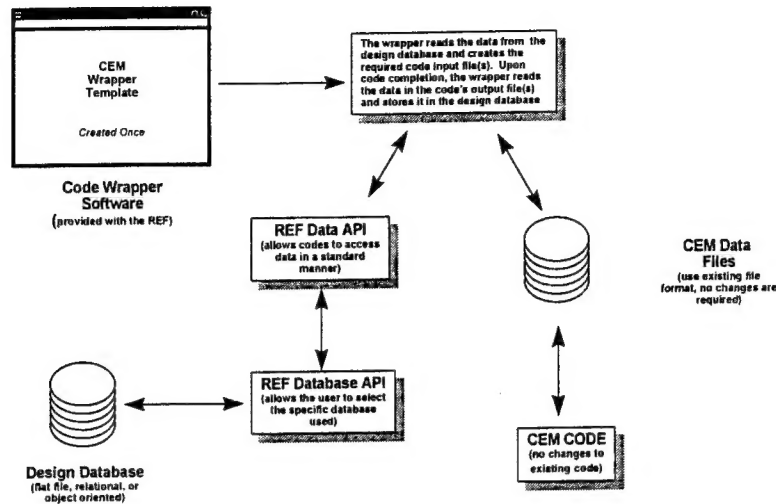


Figure 3. Code Interface with the REF

A second process of incorporating an existing application into the REF is to integrate the REF API (Application Programmer Interface) function calls directly into the code as shown in the following figure. Here the programmer has replaced the legacy code data I/O with REF database API function calls. These functions would be used to retrieve the required analysis data directly from the database for use by the application rather than using intermediate file I/O. In addition to the database API functions the user will also have available all the graphical API functions to display the results of the analysis that is performed on the input data.

The key piece to making this process of integrating legacy codes into the REF is having an accurate extensible data dictionary for the legacy code or discipline that the code belongs to. The remainder of this report describes the data dictionary for the CEM (Computational Electromagnetics) discipline.

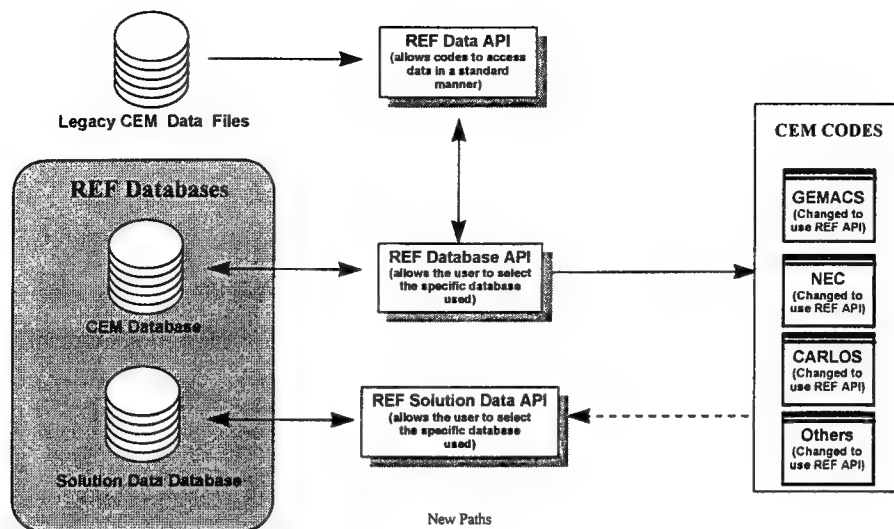


Figure 4. Code Integration with the REF

4. CEM ANALYSIS TECHNIQUES

Computational electromagnetics encompasses several different mathematical formulations. These formulations may or may not reside in any given CEM Code. The CEM data dictionary has been developed such that the required data for each of these formulations can be stored. The following list gives a short description of the formulations addressed by the current design of the data dictionary.

- **The Method of Moments(MOM)**

The geometry is modeled by a number of electrically small straight-wire subsections and/or by a number of electrically small subareas (or patches). Each of these elements is then treated as a point source radiating to, and interacting with, all of the other elements making up the system geometry. These various interactions are represented by a set of simultaneous equations, which is represented in a matrix notation and solved by a suitable solution process. Given the boundary conditions and the external electromagnetic environment, the currents on the subsections and/or the current densities on the subareas are calculated for a particular frequency. Once these currents and current densities are known, it is then a simple matter of matrix multiplication with a suitable Green's function to obtain the field at any point (or series of points) in the near or far field of the structure. Coupling between the terminals of antennas and the input impedance of any antenna fall out of the solution with ultimate ease. Proper positioning and incrementing of the source with respect to the structure under consideration will allow one to calculate the monostatic and/or bistatic cross section of the object.

- **Geometric Theory of Diffraction/Uniform Theory of Diffraction (GTD/UTD)**

When using the GTD formulation for the analysis of a structure, one models the system geometry as a set of plates and cylinders with endcaps. The electric field at one or more points of interest is then computed using ray tracing techniques, following the ray from the source through a series of reflections and/or diffractions from plates, cylinders, plate edges, and endcap rims. Each such scattering center is treated as a local source of electromagnetic energy, and the contributions from all such localized sources are summed at the field point. In this formulation the current distribution on the structure is not calculated. However, the code can calculate such observables as the electric field distribution in the near and far field of the object, the coupling between antennas, the radar cross section, etc.

- **Finite Difference Frequency Domain and Time Domain (FDFD/FDTD)**
The finite difference techniques allow for the solution of interior or cavity-type problems. Based on the differential form of Maxwell's equations, FD divides it region into a number of small cells. Within each cell the differential equations are modeled with finite difference equations. Between pairs of adjacent cells the equations are matched to ensure continuity of tangential electric and magnetic fields. The lattice of FD cells is the most distinguishing characteristic of this method. To this cell model is added cavity walls, thin wires, dielectric regions, and sources to model the system to be analyzed.
- **Shooting and Bouncing Rays**
In the Shooting and Bouncing Rays (SBR) technique a dense grid of rays is transmitted from the source direction toward the target (system under analysis). The rays are traced based on the principles of geometrical optics theory as they bounce around on the target. The effects of polarization, ray divergence, layered materials transmission or reflection are all included in the ray tracing. Wherever a ray exits the target a physical optics integration is done to calculate the scattered far field from the target. The SBR concept uses models of the system consisting of either flat facet approximations of the geometry or a combinational solid geometry/non-uniform rational b-splines representation of the geometry. Thus a high level of detail can be generated using the SBR technique.

5. DATA DICTIONARY MASTER RELATION

The CEM data dictionary is designed as a set of relations with the Master relation as the core interface into the dictionary. The Master relation contains information that points to information in the data dictionary that will uniquely define a CEM analysis input stream. As shown in the following figure the Master relation is connected to the Sources relation for input excitation values, the Observables relation to define observable values, the Frequency relation to define the applicable frequency(s) for the analysis and the Geometry Region (GMRegion) relation for including a physical structure in the analysis. Following the figure is a table describing the various attributes of the Master relation.

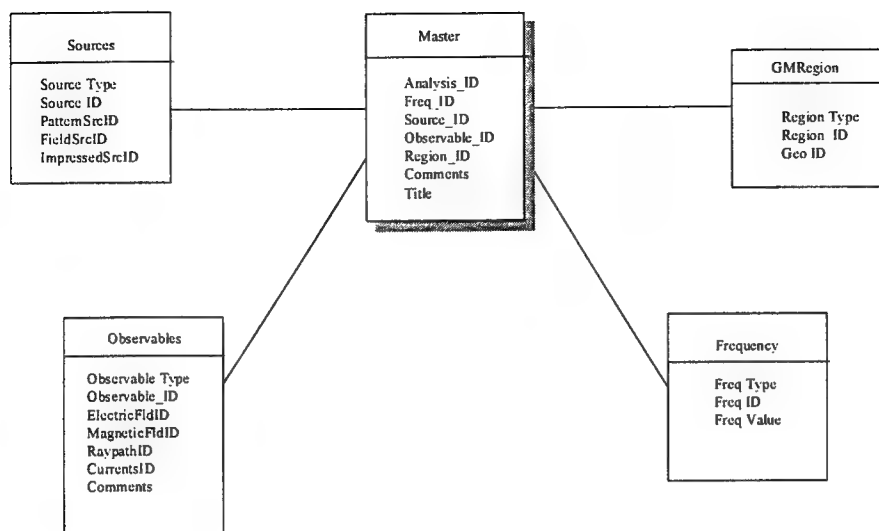


Figure 5. CEM Data Dictionary "Master Relation"

Table 1. Attributes in the Master Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Analysis_ID	number(integer)	Identification number of this analysis.	N/A	≥ 1
Frequency_ID	number(integer)	Identification number of the frequency set in the frequency table	N/A	≥ 1
Source_ID	number(integer)	Identification number of the set of sources in the sources table	N/A	≥ 1
Observable_ID	number(integer)	Identification number of the set of observable commands in the observables table	N/A	≥ 1
Title	text	Title of the analysis	N/A	80 chars
Region_ID	number(integer)	Identification number of the geometry region set in the geometry region table	N/A	≥ 0
Comments	memo	Space for notes on the analysis.	N/A	N/A

6. EXCITATION

The tables and relations in this section are designed such that the database can store descriptions of the type, quantity, and location of the excitation that is to be applied in the analysis. The goal here is to provide a flexible extensible data dictionary so that the existing excitation types can be represented

and as other excitation types/subtypes are developed their inclusion in the data dictionary will be straightforward.

- Waveform Information
 - ⇒ Plane Wave
 - ⇒ Spherical Wave
 - ⇒ Polarization
 - ◇ Vertical
 - ◇ Horizontal
 - ◇ Circular (Left or Right)
 - ◇ Elliptical
- Location
 - ⇒ 3-Dimensional coordinates (Rectangular, Spherical, Cylindrical)
- Loading
 - ⇒ Lumped
 - ⇒ Distributed
- Source Parameters
 - ⇒ Gain, Beamwidth
 - ⇒ Field Source
 - ⇒ Impressed Source
 - ⇒ Measured Pattern Source

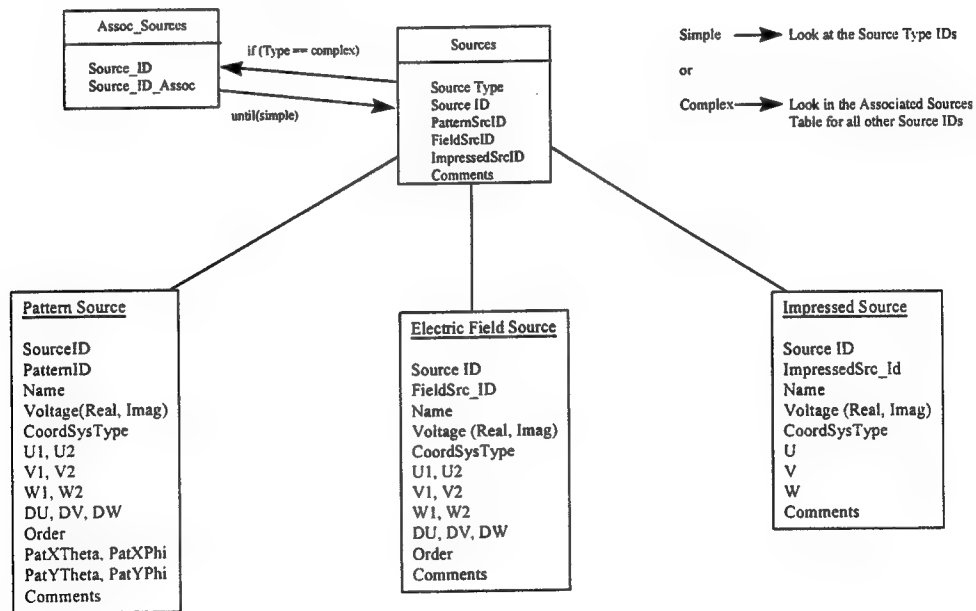


Figure 6. CEM Data Dictionary "Sources Relation"

Table 2. Attributes in the Sources Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Source_type	text	Text string identifying what type of source this record points. If complex search Assoc_Sources Table for all Sources with the same Source_ID.	N/A	Impressed, Field, Pattern, or complex
Source_ID	number(integer)	Identification number of this source.	N/A	≥ 1
PatternSrc_ID	number(integer)	Identification number of the pattern source given in the pattern source table	N/A	≥ 0
FieldSrc_ID	number(integer)	Identification number of the field source given in the field source table	N/A	≥ 0
ImpressedSrc_ID	number(integer)	Identification number of the impressed source given in the impressed source table	N/A	≥ 0
Comments	memo	Space for notes on the sources.	N/A	N/A

One goal of modeling a system to perform analyses is to classify portions of the model according to their physical world component. These could include, in the case of an aircraft, wings, tail, fuselage, communication antenna, radar, etc. Each of these named components would possibly consist of numerous CEM basic elements, wire subsections, plates, cylinders, sources, etc. The design of the data dictionary allows the analyst to maintain this representation of complex entities consisting of low level CEM entities. This is accomplished by using associated entity relations such as is shown in the following table for the Assoc_Sources relation.

Table 3. Attributes in the Assoc_Sources Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Source_ID	number(integer)	Identifier from Sources table of a complex source.	N/A	≥ 1
Source_ID_assoc	number(integer)	ID of Simple source in the source table associated with the complex source	N/A	≥ 1

The associated relation works in the following manner. Should a complex source need to be stored for an analysis an entry is made in the Sources relation indicating that this source is complex. The multiple sources that represent this complex source are also stored in the Sources relation as simple sources. The method for connecting the complex source entry with the simple source entry lies in the Assoc_Sources relation. For every simple source that makes up the complex source there will be an entry in the Assoc_Sources relation That gives the id of the complex source and the id in the Sources relation of the simple source that belongs to the complex source.

As an example consider an array antenna that is composed of five radiating elements, each modeled as a field source. The entries in the Source relation would include the following information:

<u>id</u>	<u>Source type</u>	<u>Source id</u>	<u>PatternSrc ID</u>	<u>FieldSrc ID</u>	<u>ImpressedSrc ID</u>
1	complex	1	0	0	0
2	field	2	0	1	0
3	field	3	0	2	0
4	field	4	0	3	0
5	field	5	0	4	0
6	field	6	0	5	0

The entries in the Assoc_Sources relation indicating that sources 2-6 are part of the complex source (Source_id=1) would be:

<u>id</u>	<u>Source ID</u>	<u>Source ID assoc</u>
1	1	2
2	1	3
3	1	4
4	1	5
5	1	6

Thus by scanning through the Assoc_Sources relation we can see the complex source id=1 is composed of the sources identified by ids 2-6. This form of breaking down a complex entity into component parts can be used for multiple layers of components by having the Assoc_Relation point back to another less complex entity in the main relation which in turn will point to its component entities. In this manner a very complex structure can be efficiently stored without a complex database structure. The use of the associated tables is used throughout the CEM data dictionary. Its use is consistent throughout.

Table 4. Attributes in the Pattern Source Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
PatternSrc_ID	number(integer)	Identification number of the pattern source.	N/A	≥ 1
Name	text	Textual description of the pattern source	N/A	20 Chars
VoltageReal	number(float)	Real part of the voltage multiplier for the pattern source	v	± Large
VoltageImag	number(float)	Imaginary part of the voltage multiplier for the pattern source	v	± Large
CS_type	number(integer)	Type of coordinate system used to define the location of the pattern source (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1 - 3
U1	number(float)	Starting value for the 1 st coordinate system component for the pattern source location	m, m, m	± Large
V1	number(float)	Starting value for the 2 nd coordinate system component for the pattern source location	m, deg, deg	± Large
W1	number(float)	Starting value for the 3 rd coordinate system component for the pattern source location	m, deg, m	± Large
U2	number(float)	Ending value for the 1 st coordinate system component for the pattern source location	m, m, m	± Large
V2	number(float)	Ending value for the 2 nd coordinate system component for the pattern source location	m, deg, deg	± Large
W2	number(float)	Ending value for the 3 rd coordinate system component for the pattern source location	m, deg, m	± Large
DU	number(float)	Step size along 1 st component of the coordinate system.	m, m, m	± Large
DV	number(float)	Step size along 2 nd component of the coordinate system.	m, deg, deg	± Large
DW	number(float)	Step size along 3 rd component of the coordinate system.	m, deg, m	± Large
Order	number(integer)	Order of precedence in the generation of pattern source points. (1:UVW, 2:UWV, 3:VUW, 4:VWU, 5:WUV, 6:WVU)	N/A	1 - 6
PatXTheta	number(float)	The pattern sources x-axis theta angle.**	deg.	0-360
PatXPhi	number(float)	The pattern sources x-axis phi angle. **	deg.	0-360
PatYTheta	number(float)	The pattern sources y-axis theta angle. **	deg	0-360
PatYPhi	number(float)	The pattern sources y-axis phi angle. **	deg	0-360
Comments	memo	Space for notes on the pattern source.	N/A	N/A

± Large indicates that the value can take on the largest number that can be represented on the computer both positive (+Large) and negative (- Large). This range indicator will be used throughout the rest of the report for values that have valid positive and negative numbers as large as can be represented.

**The pattern source orientation is calculated relative to the pattern's local coordinate system. The local coordinate system for the pattern is the coordinate system used to generate the pattern source. These 4 rotation angles allow the pattern to be rotated to an appropriate look angle.

Table 5. Attributes in the Electric Field Source Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
FieldSrc_ID	number(integer)	Identification number of the field source.	N/A	≥ 1
Name	text	Textual description of the field source	N/A	20 Chars
VoltageReal	number(float)	Real part of the voltage for the field source	v	\pm Large
VoltageImag	number(float)	Imaginary part of the voltage for the field source	v	\pm Large
Polarization		Type of polarization		Vertical Horizontal Circular Elliptical
CS_type	number(integer)	Type of coordinate system used to define the location of the field source (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1-3
U1	number(float)	Starting value for the 1 st coordinate system component for the field source location	m, m, m	\pm Large
V1	number(float)	Starting value for the 2 nd coordinate system component for the field source location	m, deg, deg	\pm Large
W1	number(float)	Starting value for the 3 rd coordinate system component for the field source location	m, deg, m	\pm Large
U2	number(float)	Ending value for the 1 st coordinate system component for the field source location	m, m, m	\pm Large
V2	number(float)	Ending value for the 2 nd coordinate system component for the field source location	m, deg, deg	\pm Large
W2	number(float)	Ending value for the 3 rd coordinate system component for the field source location	m, deg, m	\pm Large
DU	number(float)	Step size along 1 st component of the coordinate system.	m, m, m	\pm Large
DV	number(float)	Step size along 2 nd component of the coordinate system.	m, deg, deg	\pm Large
DW	number(float)	Step size along 3 rd component of the coordinate system.	m, deg, m	\pm Large
Order	number(integer)	Order of precedence in the generation of field source points. (1:UVW, 2:UWV, 3:VUW, 4:VWU, 5:WUV, 6:WVU)	N/A	1 - 6
Comments	memo	Space for notes on the electric field source.	N/A	N/A

Table 6. Attributes in the Impressed Source Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
ImpressedSrc_ID	number(integer)	Identification number of the impressed source	N/A	≥ 1
Name	text	Textual description of the impressed source	N/A	20 Chars
VoltageReal	number(float)	Real part of the voltage for the impressed source	v	\pm Large
VoltageImag	number(float)	Imaginary part of the voltage for the impressed source	v	\pm Large
CS_type	number(integer)	Type of Coordinate system used to define the location of the field source (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1-3
U	number(float)	value of 1 st coordinate system component for the impressed source location	m, m, m	\pm Large
V	number(float)	value of 2 nd coordinate system component for the impressed source location	m, deg, deg	\pm Large
W	number(float)	value of 3 rd coordinate system component for the impressed source location	m, deg, m	\pm Large
Comments	memo	Space for notes on the impressed source.	N/A	N/A

7. OBSERVABLES

The Observables relation allows the user to specify the different observables he or she wishes to obtain from the analysis. The following list shows the types of observables implemented in the CEM Data Dictionary. This list can easily be extended to include other types of observables as they are developed or added to the analysis codes.

- Fields
 - ⇒ Electric Field, Magnitude, Phase
 - ⇒ Magnetic Field, Magnitude, Phase
- Ray Paths
- Currents on the structure

Through the use of the Assoc_Observables relation a virtually unlimited number of observable definitions can be requested from one analysis. The following figure shows the connectivity between Observables relation and the individual observable types relations. Following the figure are tabular descriptions of the attributes in each relation shown in the figure.

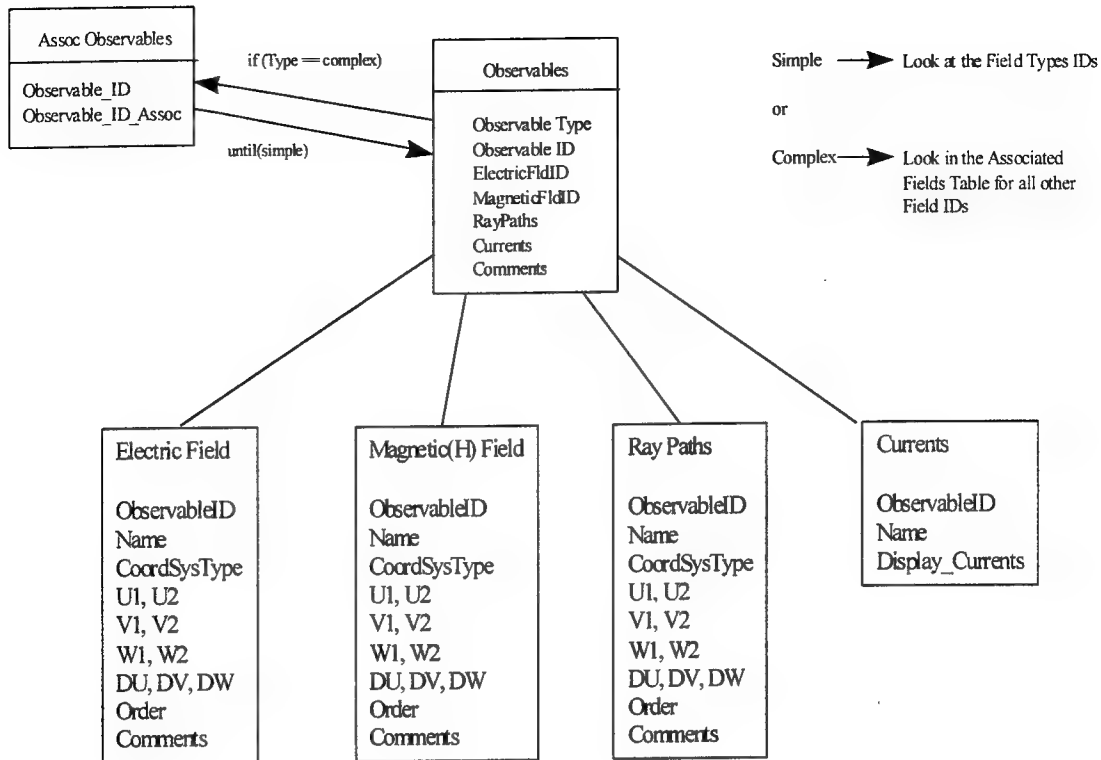


Figure 7. CEM Data Dictionary "Observables Relation"

Table 7. Attributes in the Observables Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Observable_type	text	Text string identifying what type of field this record points. If complex search Assoc_Fields Table for all fields with the same Field_ID.	N/A	ElecField MagField Raypath Current Complex
Observable_ID	number(integer)	Identification number of this field.	N/A	≥ 1
ElectricFld_ID	number(integer)	Identification number of the electric field given in the electric field table	N/A	≥ 0
MagneticFld_ID	number(integer)	Identification number of the magnetic field given in the magnetic field table	N/A	≥ 0
RayPath_ID	number(integer)	Identification number of the Ray Path given in the RayPath table	N/A	≥ 0
Currents_ID	number(integer)	Identification number of the Currents given in the Currents table	N/A	≥ 0
Comments	memo	Space for notes on the field commands.	N/A	N/A

Table 8. Attributes in the Assoc_Observables Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Observable_ID	number(integer)	Identifier from observables table of a complex observable.	N/A	≥ 1
Observable_ID_assoc	number(integer)	ID of Simple observable in the observables table associated with the complex observable.	N/A	≥ 1

Table 9. Attributes in the Electric Field Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
ElectricFld_ID	number(integer)	Identification number of the electric field	N/A	≥ 1
Name	text	Textual description of the electric field	N/A	20 Chars
CS_type	number(integer)	Type of coordinate system used to define the location of the pattern source (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1 - 3
U1	number(float)	Starting value for the 1 st coordinate system component for the field source location	m, m, m	± Large
V1	number(float)	Starting value for the 2 nd coordinate system component for the field source location	m, deg, deg	± Large
W1	number(float)	Starting value for the 3 rd coordinate system component for the field source location	m, deg, m	± Large
U2	number(float)	Ending value for the 1 st coordinate system component for the field source location	m, m, m	± Large
V2	number(float)	Ending value for the 2 nd coordinate system component for the field source location	m, deg, deg	± Large
W2	number(float)	Ending value for the 3 rd coordinate system component for the field source location	m, deg, m	± Large
DU	number(float)	Step size along 1 st component of the coordinate system.	m, m, m	± Large
DV	number(float)	Step size along 2 nd component of the coordinate system.	m, deg, deg	± Large
DW	number(float)	Step size along 3 rd component of the coordinate system.	m, deg, m	± Large
Order	number(integer)	Order of precedence in the generation of field source points. (1:UVW, 2:UWV, 3:VUW, 4:VWU, 5:WUV, 6:WVU)	N/A	1 - 6
Comments	memo	Space for notes on the electric field command.	N/A	N/A

Table 10. Attributes in the Magnetic Field Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
MagneticFld_ID	number(integer)	Identification number of the magnetic field	N/A	≥ 1
Name	text	Textual description of the magnetic field	N/A	20 Chars
CS_type	number(integer)	Type of coordinate system used to define the location of the pattern source (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1 - 3
U1	number(float)	Starting value for the 1 st coordinate system component for the field source location	m, m, m	\pm Large
V1	number(float)	Starting value for the 2 nd coordinate system component for the field source location	m, deg, deg	\pm Large
W1	number(float)	Starting value for the 3 rd coordinate system component for the field source location	m, deg, m	\pm Large
U2	number(float)	Ending value for the 1 st coordinate system component for the field source location	m, m, m	\pm Large
V2	number(float)	Ending value for the 2 nd coordinate system component for the field source location	m, deg, deg	\pm Large
W2	number(float)	Ending value for the 3 rd coordinate system component for the field source location	m, deg, m	\pm Large
DU	number(float)	Step size along 1 st component of the coordinate system.	m, m, m	\pm Large
DV	number(float)	Step size along 2 nd component of the coordinate system.	m, deg, deg	\pm Large
DW	number(float)	Step size along 3 rd component of the coordinate system.	m, deg, m	\pm Large
Order	number(integer)	Order of precedence in the generation of field source points. (1:UVW, 2:UWV, 3:VUW, 4:VWU, 5:WUV, 6:WVU)	N/A	1 - 6
Comments	memo	Space for notes on the magnetic field command.	N/A	N/A

Table 11. Attributes in the Ray Path Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
RayPath_ID	number(integer)	Identification number of the ray paths	N/A	≥ 1
Name	text	Textual description of the ray paths	N/A	20 Chars
CS_type	number(integer)	Type of coordinate system used to define the location of the Ray Paths (1:Rectangular, 2:Polar, 3:Cylindrical)	N/A	1 - 3
U1	number(float)	Starting value for the 1 st coordinate system component for the ray paths location	m, m, m	\pm Large
V1	number(float)	Starting value for the 2 nd coordinate system component for the ray paths location	m, deg, deg	\pm Large
W1	number(float)	Starting value for the 3 rd coordinate system component for the ray paths location	m, deg, m	\pm Large
U2	number(float)	Ending value for the 1 st coordinate system component for the ray paths location	m, m, m	\pm Large
V2	number(float)	Ending value for the 2 nd coordinate system component for the ray paths location	m, deg, deg	\pm Large
W2	number(float)	Ending value for the 3 rd coordinate system component for the ray paths location	m, deg, m	\pm Large
DU	number(float)	Step size along 1 st component of the coordinate system.	m, m, m	\pm Large
DV	number(float)	Step size along 2 nd component of the coordinate system.	m, deg, deg	\pm Large
DW	number(float)	Step size along 3 rd component of the coordinate system.	m, deg, m	\pm Large
Order	number(integer)	Order of precedence in the generation of field source points. (1:UVW, 2:UWV, 3:VUW, 4:VWU, 5:WUV, 6:WVU)	N/A	1 - 6
Comments	memo	Space for notes on the ray path command.	N/A	N/A

Table 12. Attributes in the Currents Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Currents_ID	number(integer)	Identification number of the currents	N/A	≥ 1
Name	text	Textual description of the currents	N/A	20 Chars
DisplayCurrents	Boolean	Boolean value that indicates whether currents on the wire model should be output to a data file.	N/A	TRUE FALSE
Comments	memo	Space for notes on the magnetic field command.	N/A	N/A

8. FREQUENCY

The Frequency relation is set up such that the user can store discrete frequency values or a start frequency, stop frequency and a frequency step size to allow for codes that can use swept frequency input. As in the previous sections the associated frequency relation is used to store multiple discrete values of frequency in the relation. The following figure shows the connectivity between Frequency and Assoc_Frequency relations. Following the figure are tabular descriptions of the attributes in each relation shown in the figure.

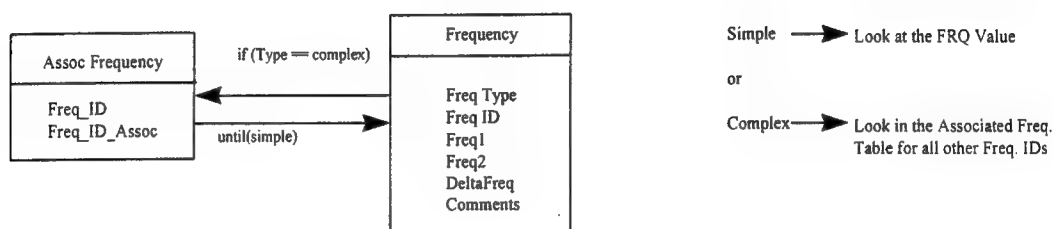


Figure 8. CEM Data Dictionary "Frequency Setting Relation"

Table 13. Attributes in the Frequency Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Frequency_type	text	Description of whether the frequency is a simple frequency setting or a complex frequency setting. If complex search Assoc_Frequency Table for all fields with the same Frequency_ID.	N/A	Simple Complex
Frequency_ID	number(integer)	Identification number of this frequency setting.	N/A	≥ 1
Frequency1	number(float)	Starting Frequency value	MHz	> 0.0
Frequency2	number(float)	Ending Frequency value	MHz	> Frequency1
Delta_Frequency	number(float)	Frequency step value	MHz	≥ 0.0
Comments	memo	Space for notes on the frequency values.	N/A	N/A

Table 14. Attributes in the Assoc_Frequency Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Freq_ID	number(integer)	Identifier from Frequency table of a complex frequency	N/A	≥ 1
Freq_ID_assoc	number(integer)	ID of Simple frequency in the frequency table associated with the complex frequency.	N/A	≥ 1

9. CEM GEOMETRY ELEMENTS

The GMRegion relation allows the user to specify and store a description of the structure for analysis. The goal here as in the earlier sections is to provide a flexible extensible data dictionary so that as many of the existing geometry elements can be represented and as other elements are developed their inclusion in the data dictionary will be straightforward. The following list shows the types of geometry elements broken down by CEM technique that are currently defined in the CEM Data Dictionary. This list can easily be extended to include other types of geometry as they are developed or added to the analysis codes.

- MOM
 - ⇒ Wire Subsections
 - ⇒ Surface Patches
- GTD/UTD
 - ⇒ Plates
 - ⇒ Cylinders/Endcaps
 - ⇒ Ellipsoids
 - ⇒ Cone / Frustum
- Shooting and Bouncing Rays
 - ⇒ Facets
- Miscellaneous Geometry Data Objects
 - ⇒ Points
 - ⇒ Coordinate Systems

The following figure shows the connectivity between GMRegion relation, Assoc_GMRegion relation and the Geometry relation. Following the figure are tabular descriptions of the attributes in each relation shown in the figure. This configuration allows the user to describe at a higher level the different parts of the structure under analysis. Instead of trying to remember what group of geometry elements is used to form a piece of the structure the user can combine these into one geometry region and give that region a more descriptive name.

An example geometry of an aircraft could contain regions for the fuselage, wings, control surfaces and engines. Also these regions can be combined into a higher level region called airplane for example. Each of these regions would then be further described by the individual modeling elements that they are made of in the Geometry relation and subrelations that are described in the subsequent paragraphs and tables.

The process of creating regions from parts of the structure gives rise to the capability to reuse whole sections of a structure in different configurations. An aircraft model could be developed with one set of engine pylons and should a change be required the pylons can easily be swapped out for a different configuration to allow for a new analysis.

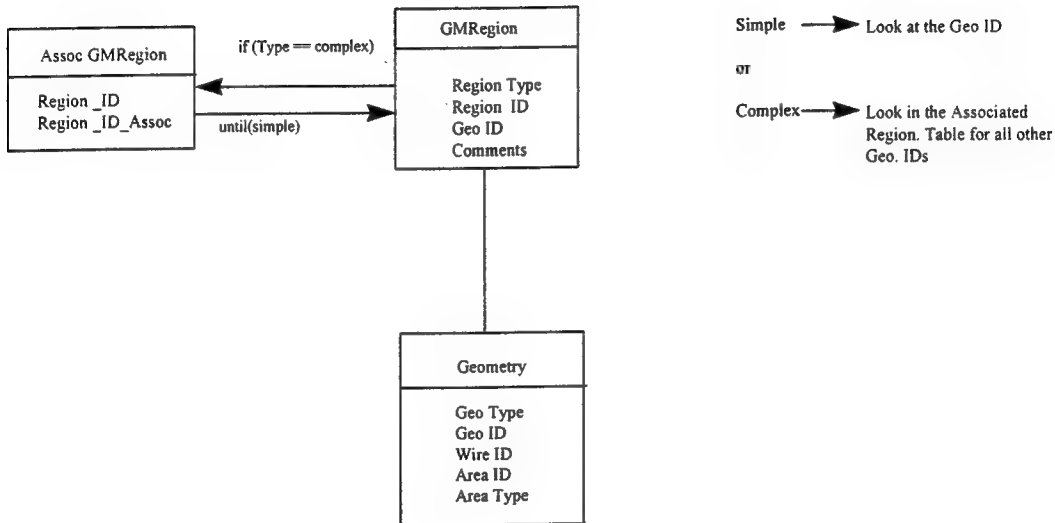


Figure 9. CEM Data Dictionary "Geometry Regions Relation"

Table 15. Attributes in the GMRegion Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Region_Type	text	Description of whether the geometry region is a simple region or a complex region. If complex search Assoc_GMRegion Table for all fields with the same Region_ID.	N/A	Simple Complex
Region_ID	number(integer)	Identification number of this geometry region.	N/A	≥ 1
Descr	text	Short description of the geometry region	N/A	80 Chars
Name	text	Name given to this geometry region.	N/A	80 Chars
Comments	memo	Space for notes on the geometry region.	N/A	N/A

Table 16. Attributes in the Assoc_GMRegion Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
GMRegion_ID	number(integer)	Identifier from GMRegion table of a complex geometry region.	N/A	≥ 1
GMRegion_ID_assoc	number(integer)	ID of Simple geometry region in the GMRegion table associated with the complex geometry region.	N/A	≥ 1

The geometry region described in the preceding paragraph is related to the individual modeling elements according to the Geometry relation. The Geometry relation allows the user to specify the different elements, wires, plates, cylinders, etc., that comprise a geometry region. Using the figure below with the previous example of an aircraft the fuselage of the aircraft could be described and stored in the database as a cylinder with two end caps. The other regions of the structure can likewise be described. Through the use of the Assoc_Geometry relation a virtually unlimited number of elements can be combined into one geometry region.

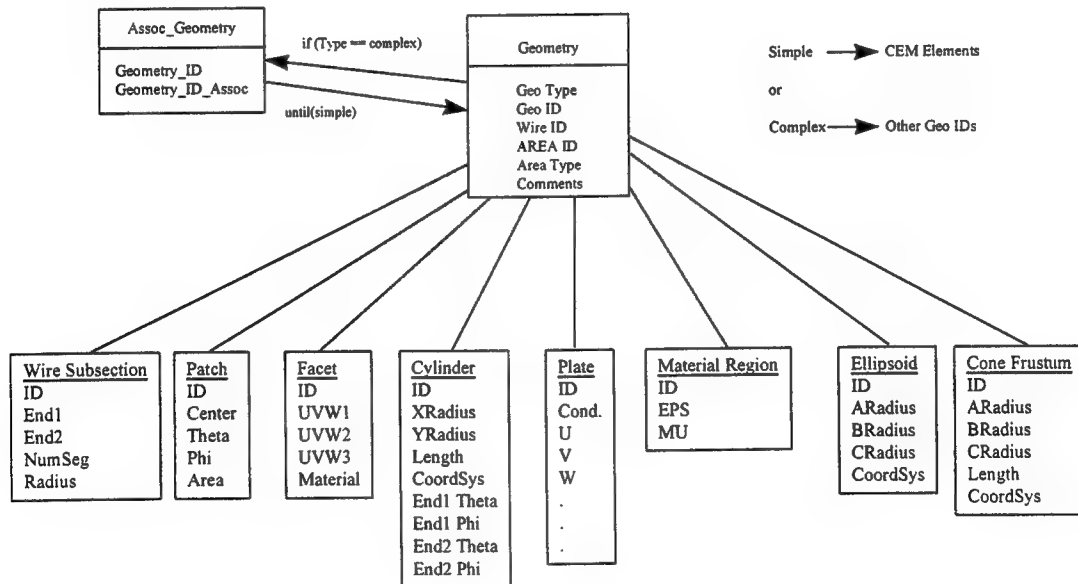


Figure 10. CEM Data Dictionary "Geometry Relation"

Table 17. Attributes in the Geometry Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Geo_Type	text	Description of whether the geometry is a simple geometry or a complex geometry. If complex search Assoc_Geometry Table for all fields with the same Geo_ID.	N/A	Simple Complex
Geo_ID	number(integer)	Identification number of this geometry.	N/A	≥ 1
Wire_ID	number(integer)	Identification number of the wire given in the wire subsection table. (This attribute is not applicable for an Area geometry type.)	N/A	≥ 0
Area_ID	number(integer)	Identification number of the area given in the various area tables. (This attribute is not applicable for an wire subsection geometry type.)	N/A	≥ 0
Area_Type	text	Type of area this record points to	N/A	Plate Cylinder Endcap Cone Facet Patch
Comments	memo	Space for notes on the geometry.	N/A	N/A

Table 18. Attributes in the Assoc_Geometry Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Geom_ID	number(integer)	Identifier from Geometry table of a complex geometry.	N/A	≥ 1
Geom_ID_assoc	number(integer)	ID of Simple geometry in the Geometry table associated with the complex geometry.	N/A	≥ 1

Table 19. Attributes in the Wire Subsection Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Wire_ID	number(integer)	Identifier of this segment or set of segments	N/A	≥ 1
XCoord1	number(float)	X coordinate of 1 st end point of the wire object	m	\pm Large
YCoord1	number(float)	Y coordinate of 1 st end point of the wire object	m	\pm Large
ZCoord1	number(float)	Z coordinate of 1 st end point of the wire object	m	\pm Large
XCoord2	number(float)	X coordinate of 2 nd end point of the wire object	m	\pm Large
YCoord2	number(float)	Y coordinate of 2 nd end point of the wire object	m	\pm Large
ZCoord2	number(float)	Z coordinate of 2 nd end point of the wire object	m	\pm Large
Segments	number(integer)	Number of subsections defined by this modeling object	N/A	≥ 1
Radius	number(float)	Radius value of the wire segments.	m	> 0.0
Comments	memo	Space for notes on the wire.	N/A	N/A

Table 20. Attributes in the Patch Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Patch_ID	number(integer)	identifier of this patch	N/A	≥ 1
XCenter	number(float)	X coordinate of the Center point of the patch	m	\pm Large
YCenter	number(float)	Y coordinate of the Center point of the patch	m	\pm Large
ZCenter	number(float)	Z coordinate of the Center point of the patch	m	\pm Large
Theta	number(float)	The polar angle for the normal vector of the patch	deg	≥ 0 ≤ 180
Phi	number(float)	The azimuth angle for the normal vector of the patch	deg	≥ 0 ≤ 360
Area	number(float)	The surface area of the patch	m ²	> 0
Comments	memo	Space for notes on the patch.	N/A	N/A

Table 21. Attributes in the Facet Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table.	N/A	≥ 1
Facet_ID	number(integer)	identifier of this facet	N/A	≥ 1
material	number(integer)	Facet Material type	N/A	≥ 0
XCoord1	number(float)	X coordinate of 1 st end point of the wire object	m	\pm Large
YCoord1	number(float)	Y coordinate of 1 st corner of the patch object	m	\pm Large
ZCoord1	number(float)	Z coordinate of 1 st corner of the patch object	m	\pm Large
XCoord2	number(float)	X coordinate of 2 nd corner of the patch object	m	\pm Large
YCoord2	number(float)	Y coordinate of 2 nd corner of the patch object	m	\pm Large
ZCoord2	number(float)	Z coordinate of 2 nd corner of the patch object	m	\pm Large
Xcoord3	number(float)	X coordinate of 3 rd corner of the patch object	m	\pm Large
Ycoord3	number(float)	Y coordinate of 3 rd corner of the patch object	m	\pm Large
Zcoord3	number(float)	Z coordinate of 3 rd corner of the patch object	m	\pm Large
Comments	memo	Space for notes on the facet.	N/A	N/A

Table 22. Attributes in the Cylinder Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table.	N/A	≥ 1
Cylinder_ID	number(integer)	identifier of this cylinder	N/A	≥ 1
Radius 1	number(float)	X- Axis radius of the cylinder	m	> 0
Radius 2	number(float)	Y- Axis radius of the cylinder	m	> 0
Length	number(float)	Length of the cylinder	m	> 0
CoordSys_ID	number(integer)	Coordinate system defining the location and orientation of the cylinder	N/A	≥ 0
Comments	memo	Space for notes on the cylinder.	N/A	N/A

Table 23. Attributes in the Cylinder Endcap Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table.	N/A	≥ 1
EndCap_ID		Identifier number of this end cap	N/A	≥ 1
theta	number(float)	theta angle of the end cap	deg	≥ -180 ≤ 180
phi	number(float)	phi angle of the end cap	deg	≥ -180 ≤ 180
Cylinder_ID	number(integer)	Identifier of the cylinder this end cap is part of.	N/A	≥ 1
cyland	number(integer)	The end of the cylinder the end cap is on.	N/A	± 1
Comments	memo	Space for notes on the endcap.	N/A	N/A

Table 24. Attributes in the Plate Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Plate_ID	number(integer)	Identifier of this plate.	N/A	≥ 1
NumCorn	number(integer)	number of corners	N/A	> 2
Cond	number(integer)	conductivity value pointer	N/A	≥ 0
FirstPtr	number(integer)	The first point defining the perimeter of the plate	N/A	≥ 1
Comments	memo	Space for notes on the plate.	N/A	N/A

Table 25. Attributes in the Material Region Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table.	N/A	≥ 1
Material_ID	number(integer)	Identifier number of this end cap	N/A	≥ 1
EPS	number(complex)	Relative dielectric constant value of the region	N/A	≥ 0
MU	number(complex)	Relative permeability value of the region	N/A	≥ 0
Cond	number(float)	Conductivity of the region	mhos/m	≥ 0
Comments	memo	Space for notes on the dielectric region.	N/A	N/A

Table 26. Attributes in the Cone Frustum Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
ConeF_ID	number(integer)	Identifier of this cone or frustrum.	N/A	≥ 1
end1 Radius	number(float)	Radius of the bottom end of the cone	m	≥ 0
end2 Radius	number(float)	Top radius of the cone	m	≥ 0
Length	number(float)	Length of the cone	m	≥ 0
end1theta	number(float)	theta angle of bottom end of the cone	deg	$\geq -180 - \leq 180$
end1phi	number(float)	phi angle of bottom end of the cone	deg	$\geq -180 - \leq 180$
end2theta	number(float)	theta angle of top end of the cone	deg	$\geq -180 - \leq 180$
end2phi	number(float)	phi angle of top end of the cone	deg	$\geq -180 - \leq 180$
CoordSys_ID	number(integer)	Coordinate system defing the location and orientation of the cone or frustum	N/A	≥ 0
Comments	memo	Space for notes on the cone or frustum.	N/A	N/A

Table 27. Attributes in the Ellipsoid Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Ellips_ID	number(integer)	Identifier of this Ellipsoid.	N/A	≥ 1
XRradius	number(float)	x axis radius	m	> 0
YRradius	number(float)	y axis radius	m	> 0
ZRadiusN	number(float)	-z radius	m	> 0
ZRadiusP	number(float)	+z radius	m	> 0
ZEndN	number(float)	location of negative end cap	m	≥ 0
ZThetaN	number(float)	angle of negative end cap	deg	$\geq -180 - \leq 180$
ZEndP	number(float)	location of positive end cap	m	≥ 0
ZThetaP	number(float)	angle of positive end cap	deg	$\geq -180 - \leq 180$
CoordSys_ID	number(integer)	Coordinate system defining the location and orientation of the ellipsoid	N/A	≥ 0
Comments	memo	Space for notes on the ellipsoid.	N/A	N/A

The following relations are support relations for the geometry element relations above. The Point relation holds all of the data that fully describes a point in the global coordinate system. These points are used by the Wire relation and indirectly by the Plate and Patch relations via the Plate & Patch Point relation shown in the following table. This latter relation provides the equivalent of a linked list in C programming to specify the list of points that describe the perimeter of the Plate or Patch.

Table 28. Attributes in the Point Relation

Attribute	Type	Description	Units	Range
id	number(integer)		N/A	≥ 1
Point_ID	number(integer)	Identifier of this Point.	N/A	≥ 1
XCoord	number(float)	Global X coordinate of the point	m	\pm Large
YCoord	number(float)	Global Y coordinate of the point	m	\pm Large
ZCoord	number(float)	Global Z coordinate of the point	m	\pm Large
Comments	memo	Space for notes on the point.	N/A	N/A

Table 29. Attributes in the Plate & Patch Point Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
Pointer	number(integer)	id of the entity this point is a part of	N/A	≥ 1
entity	text	The type of entity this point is a part of.	N/A	Plate Patch SurfPatch
Point_ID	number(integer)	id of this point	N/A	> 0
Next Pointer	number(integer)	Pointer to the next point in the list of points for this entity. = -1 if last point in the list.	N/A	-1 or > 0

The Coordinate System relation allows for the modeler to apply a coordinate transform to modeling elements. In this version of the Data Dictionary the coordinate system is only used in defining the cylinder and ellipsoid geometry elements. These elements are initially defined along the global Z axis as in the current CEM codes. The coordinate system entry is used to move the element to the desired position.

The application of the coordinate system to other modeling elements will be expanded in the future.

Table 30. Attributes in the Coordinate System Relation

Attribute	Type	Description	Units	Range
id	number(integer)	Unique identification for this record in the table	N/A	≥ 1
CoordSys_ID	number(integer)	Identifier of this Coordinate System.	N/A	≥ 1
xtrans	number(float)	Translation along the x axis	m	\pm large
ytrans	number(float)	Translation along the x axis	m	\pm large
ztrans	number(float)	Translation along the y axis	m	\pm large
xrot	number(float)	Rotation about the z axis	deg	0 -360
yrot	number(float)	Rotation about the y axis	deg	0 -360
zrot	number(float)	Rotation about the z axis	deg	0 - 360
Comments	memo	Space for notes on the coordinate system.	N/A	N/A

10. IMPLEMENTATION

The CEM Data Dictionary can be implemented using any relational database manager that supports SQL. Below is a concept for a demonstration of the CEM Data Dictionary using the Microsoft Access Database Manager and utility routines to read and write the data to the database. Also included in Appendix A is a pseudo code listing for retrieving information from the database in the correct order in order to construct an input stream of data for any of the analysis codes.

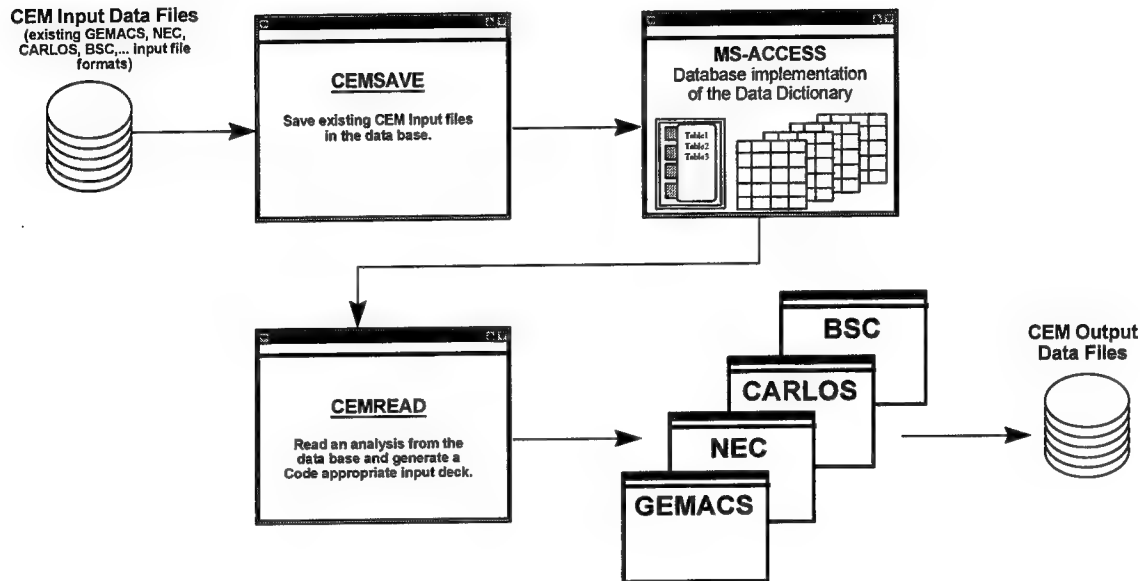


Figure 11. CEM Data Dictionary Implementation Concept

11. FUTURE DIRECTIONS/ADDITIONS TO THE DATA DICTIONARY

The core portion of the CEM Data Dictionary has been defined to be extensible in any of the primary areas with the addition of supporting relations. An attempt was made during this effort to include a broad representation of CEM analysis input requirements in a generic fashion. The desire for the future of the Data Dictionary is that it remains a generic representation of CEM and can be utilized by any existing analysis code. This will, in the near term, need to be accomplished by interface codes as described in previous sections. The ultimate goal is to have developers build their codes to the specifications of the Data Dictionary directly, thereby avoiding the requirement for interface codes and progressing toward a seamless integration of results from analyses run on different codes.

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Appendix A: Pseudo code for storage and retrieval of analysis information from a database built using the CEM data dictionary.

Select Analysis ID from a list provided from the Master Table

Using this ID select the record from the table matching the ID

Retrieve the Source ID

Retrieve the Field ID

Retrieve the Frequency ID

Retrieve the Geometry ID

Retrieve the Title

Retrieve the Comments

Add the ID, Title and Comments to the output list

if there are sources

from the sources table select the source ID that matches with the one from the master table

if this is a simple source

retrieve source inf.

add to the output list

else if this is a complex source

from the associated source table select all records matching the source ID

retrieve all associated source IDs from this set of records

for all IDs in this set

from the sources table select the record with source ID that matches

retrieve source info

add to output list

end complex retrieval

endif // simple, complex

endif // sources

if there are observables

from the observables table select the observable ID that matches with the one from the master table

if this is a simple observable

retrieve observable inf.

add to the output list

else if this is a complex observable

from the associated observable table select all records matching the observable ID

retrieve all associated observable IDs from this set of records

for all IDs in this set

from the observables table select the record with field ID that matches

retrieve observable inf.

add to output list

end complex retrieval

endif // simple, complex

endif // observables

if there are frequencies

from the frequencies table select the frequencies ID that matches with the one from the master table

if this is a simple frequency

retrieve frequency inf.

add to the output list

else if this is a complex frequency

from the associated frequencies table select all records matching the frequency ID

retrieve all associated frequency ids from this set of records

for all IDs in this set

from the frequencies table select the record with frequency ID that matches

retrieve frequency inf.

add to output list

end complex retrieval

endif // simple, complex

endif // frequencies

if there are geometry regions

from the geometry region table select the region ID that matches with the one from the master table

if this is a simple geometry region

retrieve geometry inf. (see code below)

add to the output list

else if this is a complex geometry region

from the associated geometry region table select all records matching the region ID

retrieve all associated region ids from this set of records

for all IDs in this set

from the geometry region table select the record with region ID that matches

retrieve geometry inf. (see code below)

add to output list

end complex retrieval

endif // simple, complex

endif // geometry region

Retrieve_Geometry_Info()

from geometry table select all records that have matching geometry id

for each record in this set

select geometry of type element type

case of a wire subsection:

get wire subsection inf. // see code below

case of a patch:

get patch inf. // see code below

case of a plate:

```

        get plate inf. / see code below
    case of a facet:
        get facet inf. // see code below
    case of a cylinder:
        get cylinder inf. // see code below
    case of a cone frustum:
        get cone frustum inf. // see code below
    case of an ellipsoid:
        get ellipsoid inf. // see code below
    case of a curved surface:
        get curved surface inf. / see code below
    .
    .
    .
    end // select geometry element type
end // for each record in this set
end // retrieve geometry inf.

get wire subsection inf. ()
    from table wire subsections select record with matching ID
    retrieve subsection information from the record
    end 1 (X,Y,Z)
    end2 (X,Y,Z)
    radius (X,Y)
    number of subsections
end // get wire inf.

get patch inf. ()
    from table patches select record with matching ID
    retrieve patch information from the record

end // get patch inf.

get plate inf. ()
    from table plates select record with matching ID
    retrieve plate information from the record

end // get plate inf.

get facet inf. ()
    from table facets select record with matching ID
    retrieve facet information from the record

end // get facet inf.

get cylinder inf. ()
    from table cylinders select record with matching ID
    retrieve cylinder information from the record

```

end // get cylinder inf.

get cone_frustum inf. ()

from table cone_frustum select record with matching ID
retrieve cone_frustum information from the record

end // get cone_frustum inf.

get ellipsoid inf. ()

from table ellipsoids select record with matching ID
retrieve ellipsoid information from the record

end // get ellipsoicd info

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